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ADDITIONAL INFORMATION CONCERNING THE BIOLOGY AND HABITS OF THE MOUNTAIN-PINE BEETLE IN WESTERN WHITE PINE

By
W. D. Bedard
Assistant Entomologist

Forest Insect Field Station
Coeur d'Alene, Idaho
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PREFACE

A lack of complete information concerning the biology and habits of the mountain-pine beetle (Dendroctonus monticolae Hopk.) was causing considerable confusion to administrators of control projects in matters such as the actual value of treating certain types of infested trees. Therefore, it was decided to perform a biological study with the object of securing information which would aid in the solution of these many difficult economic problems and thus result in improvements in our present control methods.

Mr. Donald DeLeon instituted the investigation during the summer of 1930 at Metaline Falls, Washington, Kaniksu National Forest, and the writer continued the project during the 1931 and 1932 field seasons.

This report contains some new facts regarding the biology and habits of the mountain-pine beetle, but much of the following data are of necessity supplementary to, and in substantiation of, the report* of the 1931 investigations. Data from the preceding report have been incorporated into this one in order to bring all existing information into one as complete report as possible.

The writer was assisted by Messrs. Francis B. Foley, David O. Scott and Lowell Farmer during the 1931 investigations and by Mr. Francis B. Foley throughout the 1932 season.

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*Bedard, W. D. 1931 - New Facts Regarding the Biology of the Mountain-pine Beetle in Western White Pine. Unpublished report.

PARENT ADULT EMERGENCE AND REATTACK

The presence of emergence holes in trees that have been too recently attacked to produce mature brood has been noted by investigators for some time. This led to a more careful examination and it was discovered by these men that the holes led from egg galleries. This suggested the possibility of parent adult emergence with subsequent attacks in a fresh host. It is obvious that if these parent adult beetles do emerge from trees after propagating one brood and reattack green trees to generate a second brood, the number of infested trees the following year will be approximately twice the number normally to be expected and will in some measure explain undue increases of this insect heretofore recorded.

In consequence of this, the problem was studied during both the 1931 and 1932 seasons by caging infested material on green trees in order to connect definitely one group of emerging parent adults with a subsequent attack. The cage used was a simple tepee made of poles and wire screen. The screen was securely sealed by tacking the top to the tree about ten feet from the ground and the overlapping sides to the poles. The base was spread sufficiently so as to allow room for the insertion of infested logs and the bottom edge of the screen was then buried in the ground.

Five such cages were constructed, two containing infested material from early attacked trees, one with infested material from a main attack, one containing infested material from a late attack, and one with infested material containing parent adults which had made their second attacks. In all but the last mentioned cage, the parent beetles did emerge and attack the green tree. Concurrent with the attacks within the enclosures, the trees were attacked

above the cages and it was noted that parent adults were emerging from the trees from which the infested material had been cut.

When the foliage had begun to fade and it was certain that the caged trees were dying, the cages were transferred to green trees. The old trees were then felled and the formerly caged portions were transferred to the cages on the green trees in order to ascertain if the parent adults would emerge and make a third attack. In only one case were third attacks found and as only three beetles emerged and attacked, it was thought that these might have been displaced in handling the logs.

All the material, both the original infested logs and the trees containing second attacks, was examined thoroughly at the conclusion of each experiment and it was found that although parent adults had emerged from their first attacks, there were many dead adults in these logs. It is known, however, that parent adults and new adults are attacking at the same time and consequently attack trees together. These dead beetles then are probably parent adults which had made their second attacks. Table I gives a summary of these findings:

TABLE I

ANALYSIS OF LOGS IN PARENT ADULT EMERGENCE CAGES

Cage	Attack	No. of Attacks	Per Cent of Parent Adult Emergence	No. of Dead Parent Adults	No. of Living Parent Adults
1	First attack June 1, 1931	282	53.5	60	2
	Second attack July 28, 1931	151	0	195	5
2	First attack June 17, 1932	290	82.0	112	18
	Second attack July 30, 1932	238	0	28	163
3	First attack Aug. 11, 1931	741	56.5	117	76
	Second attack Sept. 3, 1931	367	0	397	5
	Second attack June 16, 1932	52	0	56	4
4	First attack Aug. 28, 1932	407	18.1	23	568
	Second attack Sept. 14, 1932	74	0	89	4
5	Second attack Sept. 2, 1931	-	0	-	-

It will be noted in Table I that there are two dates for the second attacks by the beetles in cage 3. This shows that 45.5 per cent of the beetles emerged in the fall of 1931 and 7.0 per cent overwintered before emerging in the spring of 1932. The remaining 47.5 per cent did not emerge and died in the log. This emergence of parent adults during two seasons is also shown in cage 4, only in this case the attack was later and consequently the higher percentage overwintered rather than the lower. It is to be expected that the later the attack the fewer will be the number of adults which emerge in the fall.

From these studies it can be stated that mountain-pine beetle adults working in western white pine, emerge from the trees after making one attack and enter other trees to make a second attack. The mountain-pine beetle in western white pine has, therefore, two broods, one and a partial second generation instead of the one brood, one and a partial second generation heretofore believed.

PROPORTION OF SEXES

New Attacks

Investigators have reported from time to time that an unequal number of male and female beetles are to be found in the galleries of newly attacked trees. It can readily be seen that if this is due to a numerical inequality of sexes in emerging broods, the infestation will increase beyond that normally expected in direct proportion to the number of extra females and consequently the question would be an important one. Therefore, a study of the proportion of sexes was begun in 1931 and in the report of this work it was shown that in an examination of 889 galleries containing 1482 beetles in newly attacked trees, a sex ratio of two males for every three females was found and that height on the stem of the tree, exposure or date after the tree had been attacked did not effect this ratio.

In the 1932 studies, 1541 galleries containing 2528 beetles, were examined in newly attacked trees and again it was found that there were two males to every three females. These examinations were distributed over the three attack periods as shown in the following table:

TABLE II
SEX OF MOUNTAIN-PINE BEETLES FOUND IN NEWLY ATTACKED TREES
1932 SEASON

Attack period	Number of galleries	Number of females	Number of males	Sex ratio
Early	541	547*	342	5:3
Main	500	500	338	3:2
Late	500	500	301	3:2
Total	1541	1547	981	3:2

* Six galleries contained 2 females and 1 male.

It can be seen in Table II that the period of attack does not influence the sex ratio. It can, therefore, be stated that during two field seasons 2430 galleries in newly attacked white-pine trees were examined. These contained a total of 4010 mountain-pine beetles comprising 1568 males and 2442 females. Therefore, the sex ratio of mountain-pine beetles in newly attacked western white-pine trees is 2 males to 3 females.

Emerging Broods

Obviously, the importance of this numerical sex inequality depends on whether or not it originates in the emerging broods. To answer this question, 1000 new adult beetles about to emerge were dissected under the microscope to determine sex by examination of the genetalia. It was found that 497 were males and 503 females, or a sex ratio of one male to one female.

To substantiate these findings the following study was performed in 1932. Five hundred new adults were collected from trees in each of the three emergence periods; viz., early, main and late, and were examined by the same method as in 1931. Table III shows the results from this study.

TABLE III
SEX OF MOUNTAIN-PINE BEETLES EMERGING FROM BROOD TREES

Emergence period	Number of males	Number of females	Per cent males	Per cent females	Sex ratio
Early	249	251	49.8	50.2	1:1
Main	253	247	50.6	49.4	1:1
Late	248	252	49.6	50.4	1:1
Total	750	750	50.0	50.0	1:1

Combining the data from the two field seasons, 2500 beetles were examined, 1247 of which were males and 1253 females. Thus there is an equal number of males and females when the young adults emerge from the trees and an unequal sex proportion does not enter, therefore, as a factor which causes an increase of D. monticolae beyond that normally expected.

Cause of the Inequality of Sexes in Newly Attacked Trees

It has been shown that there is a loss of males somewhere between time of emergence from the old host and attack in the new host. To determine the cause of this, an experiment was performed to ascertain the sex ratio of emerging parent adult beetles prior to their second attack. Twenty square feet of newly attacked white-pine material were placed in a large galvanized can. This can was especially constructed with a bottom sloping from the sides towards a hole in the center, so that all emerging insects would fall below into a glass container. The container was emptied each day, and the sex of

each mountain-pine beetle was determined by dissecting the genetalia. When emergence was complete, it was found that 145 males and 259 females had emerged, making a sex ratio of 1:1.8 or 5:9, which is practically two females for every male.

In another experiment on June 12, 1932, eight overwintering parent adults which were alone in galleries were collected from material from which the parent adults later emerged and attacked another tree. These eight beetles were liberated individually in cages and provided with fresh white-pine material. All made attacks, laid eggs and the eggs hatched into larvae.

Thus, parent adult beetles emerge in a ratio of approximately two females to every male and mingle with new adults in attacking green trees. Also, these females are capable of laying fertile eggs without another fertilization. Although the present evidence is somewhat meagre, this is undoubtedly the most important cause of the 2:3 sex ratio found in newly attacked trees. There are in addition two other minor causes - the slightly greater number of males that fall prey to predators, and the more hazardous existence of the male beetle.

Considering the first of these secondary causes*, the male beetles, following the females into the galleries, are exposed for a somewhat longer time and consequently fall more readily as prey to predators.

Dealing with the more hazardous existence of male beetles, it is known that one male will sometimes fertilize more than one female. In this case he muse leave the original tunnel, wander off in search of the new mate, and in the course of these wanderings expose himself to constant danger and may die

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* No experiment was performed with the mountain-pine beetle, but a study made with the Douglas-fir beetle showed that when 39 male and 39 female beetles were liberated from time to time in a cage containing a green Douglas-fir log and two Clerids, 20 males and 16 females were eaten by the Clerids.

due to any one of a number of agencies. There are also more male than female beetles found buried in pitch tubes. An examination showed that there is never more than one female per pitch tube, but fairly often two males are found and in a few instances three have been recorded. Even in the successful attacks containing a male and female, there may be one or more males found buried in the pitch.

PARTHENOGENESIS AND MATING HABITS

During the 1931 season, experiments were conducted to test the possibility that D. monticolae might possess parthenogenetic ability. It was shown that this beetle can not reproduce parthenogenetically. Additional experiments on mating habits showed that fertilization takes place in the newly constructed gallery after it has progressed in the cambium from one-half to three quarters of an inch, and that one male sometimes fertilizes more than one female.

COMPLETE SEASONAL HISTORY

Although the essential features of the seasonal history of the mountain-pine beetle in white pine remain the same, much has been discovered to augment these earlier findings and at this time it is possible to write a complete seasonal history for this insect.

In the early spring before insect activity begins, three distinct overwintering brood stages are to be found in the white-pine region of northern Idaho and eastern Washington. A survey of 275 infested trees showed that 24.4 per cent contained small larvae and overwintering parent adults, 25.1 per cent contained new adult beetles, and 50.5 per cent contained mostly mature larvae. The first attacks begin early in June and continue throughout the month. These are made by the combined efforts of the overwintering parent adults from the first group of trees and the overwintering new adults from the second group.

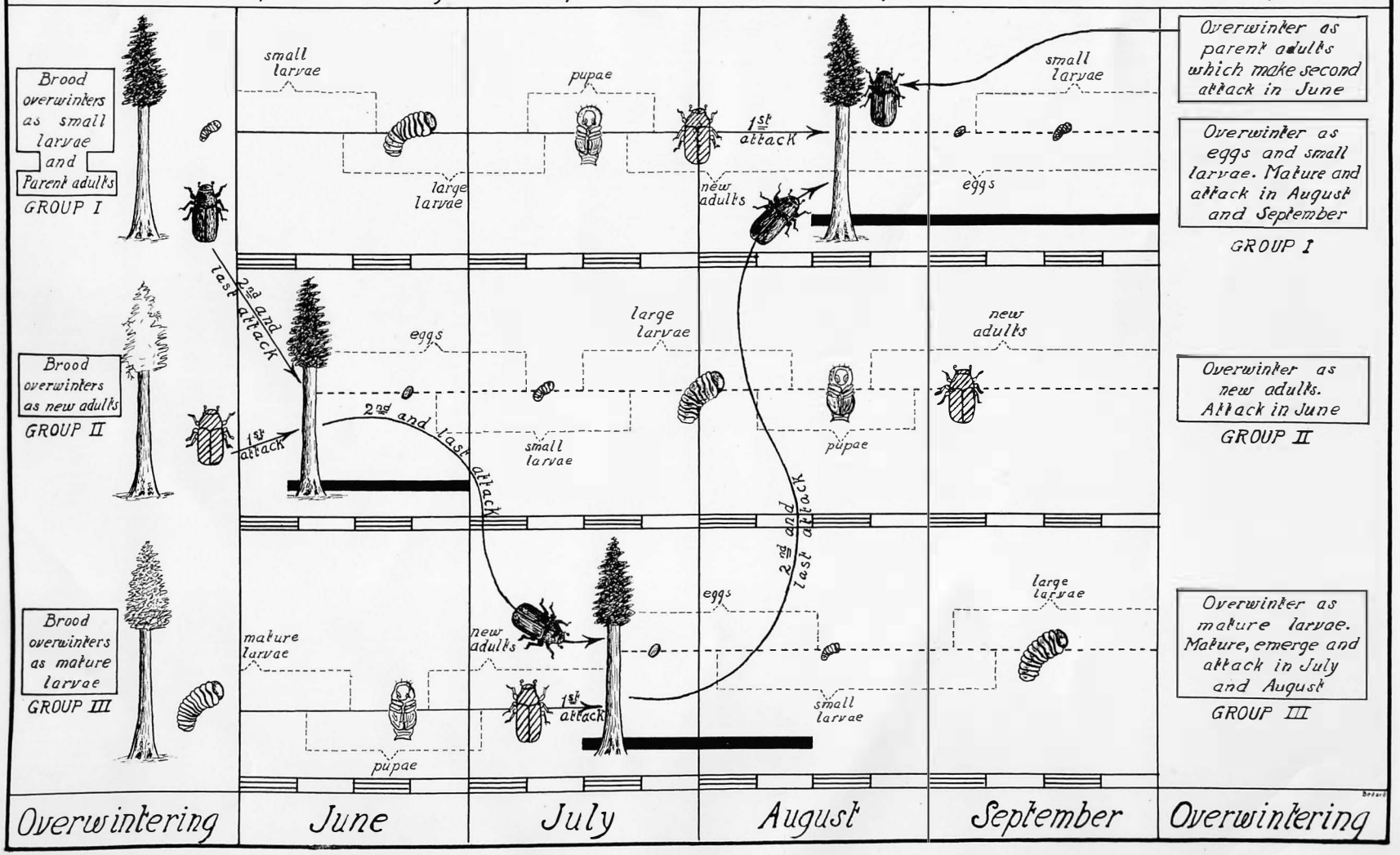
The brood from these June attacks develops normally and is mostly in the callow adult stage by the first of September. These beetles continue to feed in the trees throughout the warm days of fall; a few emerge, but the majority overwinter and emerge to attack in June of the following year. This is the brood found as new adults in the spring.

The main emergence begins near the middle of July and continues to the middle of August. This exodus comes from the trees in the third group; i.e., those containing mature larvae which have now developed into new adults, and also, the new adults which attacked in June are now emerging to attack again and generate their second and last brood. The parent adults which assisted them to make the June attacks do not emerge because they perpetrated their second and last attacks by going into the June trees. The broods generated by this main attack develop fairly rapidly and are more or less mature larvae at the close of the season, overwinter in this stage, and emerge in late July and early August of the following year. This is the brood found as mature larvae in the spring of the year.

The final attack period in reality appears as the tapering off of the main attack. It begins in the middle of August and continues to the end of the active season which is usually late in September. These attacks are made by the brood from the trees which in the spring contained small larvae that have now matured into new adults. The attacks at this time are also augmented by the parent beetles from the main attacks of July and early August which are now emerging (excepting those having already made their second attacks) and making their second attacks. This brood overwinters as small larvae and emerges during August and September of the following year. The parent adults in this group not having made their second attacks, overwinter and emerge in June of

SEASONAL HISTORY OF DENDROCTONUS MONTICOLAE HOPKINS

in Western white pine. Showing attack periods – beetles causing attacks – and brood developement



the following year to attack again.

Regarding this seasonal history, two things must be remembered. First, that no tree contains a "pure line", that is, no tree contains brood propagated entirely by new adults, or entirely by parent adults making their second attacks. Instead, inasmuch as parent adults are attacking simultaneously with new adults during all three attack periods, they attack the trees together and may be found in varying percentages in the different trees. Secondly, it must be remembered that although the sequence of events will remain the same, climate will exert a very pronounced influence on brood development and thus may change the dates of the events if the yearly climatic variations are sufficiently pronounced.

HOST SELECTION

Numerous questions are continually being asked regarding the possible spread of mountain-pine beetle infestations from one tree species to another, such as, from whitebark pine to western white pine, or from lodgepole pine to western white pine. In consequence of these questions and because of the important bearing this matter has on control recommendations, a simple experiment was performed in order to test the possibility of host selection and to determine the advisability of more detailed experiments later.

On July 6, 1932, a square wire-screen cage was constructed in an infested area of forest and ten square feet of infested white-pine bark were placed in the center of the cage. Then four-foot sections from green trees were placed in each of the four corners; one section from white pine, one from whitebark pine, one from lodgepole pine, and one from Englemann spruce.

Beetles began emerging from the infested material on July 25, and after that date a total of 337 new adult beetles collected from white pine were

liberated in the cage from time to time to insure a plentiful supply of beetles. As soon as beetles began emerging from the infested material, the white-pine log was attacked, but no attacks appeared in the other logs. On the sixth day after the first emergence, the white-pine log was removed from the cage and examined. After removal of the white-pine log, the beetles seemingly had no desire to attack the other three logs, but finally, after three days of crawling about on the screen, attacks began to appear in these logs. On August 15, 1932, the three remaining logs were examined. The following table gives the results of this study:

TABLE IV
ATTACKS BY D. MONTICOLAE IN VARIOUS HOST MATERIALS

Tree species	Date of first attacks	Date of removal of log	Number of attacks	Number of beetles
White pine	July 25	July 30	63	113
Englemann spruce	Aug. 2	August 15	56	112
Lodgepole pine	Aug. 2	August 15	47	67
Whitebark pine	Aug. 3	August 15	11	13
	Crawling on sides of cage			62
	Dead in duff			29

From examination of Table IV it would seem that there is a decided preference shown by the mountain-pine beetle in its selection of a host, white pine being preferred, when the beetles emerge from white pine; with Engelmann spruce, lodgepole pine and whitebark pine preferred in the order named. However, it is obvious that the data are entirely too meagre to use as a basis for any definite statements, but I believe they show sufficient results to warrant plans for more extensive experiments on this subject during the 1933 field season. Studies of this nature should be augmented by field observations and experiments in which infestations in one tree species are allowed to grow and watched for spread into other species of trees.

PEELING CONTROL VS. EARLY ATTACKS

Entomologists on control projects which are being performed in the spring have often questioned the advisability of peeling trees which contain new adults. These are the trees which were attacked in June of the previous year and in which the brood overwintered in the new adult stage. The brood from these trees emerges and attacks in June.

To answer this question, two white-pine windfalls which had been attacked in June 1931 were peeled on June 12, 1932. Over a portion of the peeled bark, a cage was constructed with two conical runways opening into the cage from diagonally opposite corners for the ingress of rodents and other predators. Flat pieces of sanded bark to secure the tracks of small mammals were also placed in the cage, as well as a green white-pine log for the attack of any surviving beetles. Daily footprints of small mammals (mice or chipmunks) on the sanded bark, fecal remains, and elytra of mountain-pine beetles gave evidence that rodents and other predators were destroying the beetles. In spite of this, however, when the green log in the cage was examined, it was found to contain 51 attacks.

Although this is but one experiment and contains possibilities for error, yet, when beetles are emerging from these June trees and making attacks at the same time that trees containing a similar brood stage are being peeled, the impotency of such treatment is obvious. In addition, there are the trees containing overwintering parent adults which will emerge and attack in the spring of the year. Of course the brood (small larvae) in these trees will be destroyed, but a substantial leakage is being allowed when these parent adults are turned loose. From the above it can be seen that the peeling control, when utilized in the spring, is not conducive to good results.

PARASITE STUDY

It has been suspected that certain types of trees exist in infested areas which should not be treated in control projects. These are the trees which contain brood heavily attacked by the parasite (Coeloides dendroctoni Cush.) and as the removal of the bark from these trees kills the parasite, more harm than benefit has been accomplished when such a tree is treated.

In an attempt to establish criteria whereby these trees could be distinguished, twelve days were spent with Mr. T. Terrell in the examination of treated trees on the Coeur d'Alene National Forest control project. During this period the following records were taken from 100 trees: exposure, elevation and site (relative i.e. ridge, canyon, etc.), stand, density of stand, date of attack (early, medium, or late), tree diameter, and bark thickness. None of these characters proved satisfactory for the determination of trees containing heavily parasitized broods, except that the parasites were restricted, in the trees examined, to the June and some of the late attacked trees. The reason for this restriction is apparent when it is known that the parasites prefer the fourth and fifth instar larvae and that Coeloides does not begin oviposition until July. Thus the larvae in the June attacked trees and the larvae in some of the late attacks of the previous season are the only ones available that have reached the proper instar.

All the June attacks examined were parasitized to a greater or less degree ranging from 10 per cent to nearly 100 per cent. An examination of the data taken by Mr. A. L. Gibson in 1930 while making brood counts in western white pine at Metaline Falls, Wash., showed the following: 53 square feet of bark from six "June trees" contained 8.6 parasites and 4.1 predators per square foot, while 104 square feet from trees attacked during other periods contained 1.7 parasites and 4.2 predators per square foot. In other words, parasites

comprised 24.4 per cent of the population in "June trees" and only 2.6 per cent in trees of other attack periods. Because small benefits can be expected from peeling June trees in the spring of the year, it is logical that where the peeling method is to be used, arrangements should be made to leave all June trees untreated. However, where the control is done by decking the infested logs and burning the decks, the above suggestion is not feasible until more detailed study has been made. Nevertheless there is a potential value to these parasites and a consequent need for more study to determine the way to turn the potential into actual value. To demonstrate more clearly the possibilities, let us use an hypothetical example. Let us place the average parasitism in the June trees at 20 per cent (although this is a low figure) and let us assume that our present small knowledge of the fecundity of C. dendroctoni is correct when we state that one female of this parasite is entirely capable of parasitizing all the progeny of one female mountain-pine beetle. If this were true, then in the first tree there would be ten D. monticolae larvae two of which have been parasitized and as the rates of increase would be the same the parasitism at the end of the first year would be 25 per cent, the second 33 per cent, the third year 50 per cent, and the fourth year 100 per cent. In other words, the parasite has theoretically controlled the June infestation.

However, this example serves to demonstrate the wonderful possibilities which warrant more study into matters such as the exact parasitism in various attack periods, the fecundity of C. dendroctoni and D. monticolae, the possible synchronization in development of the parasite with the brood in the July attacks, and the feasibility of large scale rearings of the parasite.

SUMMARY

Entomologists on insect control projects found a need for more complete information concerning the biology and habits of the mountain-pine beetle and a study was undertaken to secure this information.

In five caging experiments, infested sections of white pine were caged at the bases of green trees. From this it was learned that parent adult beetles emerge from the trees which they attacked first and reattack green trees, but that they make only these two attacks.

The importance of sex ratio was studied by determining the sexes of beetles in both newly attacked trees and trees from which the new brood was about to emerge. A total of 4010 beetles were examined in newly attacked trees and it was found that there were three females to every two males. Whereas, 2500 new beetles about to emerge showed a ratio of 1:1. Hence sex ratio does not account for any undue increase in the broods of D. monticolae.

Accounting for the numerical inequality of sexes in newly attacked trees, it was found that parent adults emerge in a ratio of two females for every male and these, attacking trees in unison with new adults, raise the number of females in the newly attacked trees. It is also to be noted that these female parent beetles do not require another fertilization before laying fertile eggs in the second attack.

A study of mating habits and parthenogenesis, showed that D. monticolae females do not possess parthenogenetic ability, that mating takes place in the newly constructed gallery after attack has started, and that one male may fertilize more than one female.

The seasonal history of the mountain-pine beetle shows three attack periods; late June, late July and early August, and late August to the end of

the season. Each beetle produces one generation and two broods in a twelve month period, and these broods require one year to mature. The parent beetles emerge to make their second attacks three or more weeks after their first attack.

A caging experiment concerned with host selection, indicated that the mountain-pine beetle emerging from white pine, shows a distinct preference for white pine, with Engelmann spruce, lodgepole pine, and whitebark pine next in the order given.

The peeling of trees containing brood in the new adult stage, when beetles from trees containing a similar brood stage are emerging, is not an efficient means of control.

Examination of bark from infested trees indicates that there is a concentration of parasites in the early attacked trees. If this is true, and as the peeling of these trees in the spring does not produce results, but does kill the parasites, it would be advisable to leave these trees for the parasites.

Respectfully submitted,

W. D. Bedard

W. D. Bedard,
Asst. Engomologist.